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Straws

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Common names

Straws, stover, haulms, stubble [English]; paja, rastrojo [Spanish]; paille [French]; palha, restolho [Portuguese]; stro [Dutch]; Stroh [German]; pay [Haitian]; jerami, brangkasan [Indonesian]; paglia [Italian]; damèn [Javanese]; saman [Turkish]; قش [Arabic]; 秸秆 [Chinese]; קש [Hebrew]; [Hindi]; 藁 [Japanese]; 짚 [Korean]; کاه [Persian]; Солома [Russian]; [Tamil]; [Telugu]; ฟาง [Thai]

- **Straws by species**: wheat straw, barley straw, oats straw, triticale straw, rye straw, rice straw, maize stover, sorghum straw, sorghum stover, pea straw, pea haulms, cowpea straw, cowpea haulms, groundnut straw, peanut straw, groundnut tops, peanut tops, lentil straw, chickpea straw, soybean straw, flax straw, rape straw, sunflower straw, sunflower stover
- **Treated straws**: urea-treated straw, NH_3-treated straw, ammonia-treated straw, NaOH-treated straw, sodium-hydroxide treated straw

Species

Arachis hypogaea L. ; *Cicer arietinum* L. ; *Glycine max* (L.) Merr. ; *Lens culinaris* Medik. ; *Pisum sativum* L. [Fabaceae] ; *Avena sativa* L. ; *Hordeum vulgare* L. ; *Oryza sativa* L. ; *Pennisetum glaucum* (L.) R. Br. ; *Secale cereale* L. ; *Sorghum bicolor* (L.) Moench ; *Triticum* spp. ; *Zea mays* L. ; x *Triticosecale* spp. [Poaceae]

Feed categories

- Legume forages
- Cereal and grass forages
- drilling plants
- Other plant by-products

Related feed(s)

- Soybean forage
- Pea forage
- Lentil (Lens culinaris)
- Peanut forage
- Chickpea (Cicer arietinum)
- Pearl millet (Pennisetum glaucum), forage
- Sorghum forage
- Maize stover
- Rice straw
- Rye forage
- Oat forage
- Barley forage
- Wheat forage

Description

Straw is the crop residue consisting of the dry stems and leaves left after the harvest of cereals, legumes and other crops. Straws are available in large quantities, usually over half the harvestable vegetation of the crop. Straws are a coarse, highly fibrous roughage than cannot be eaten by humans, but they have always played an important role in agriculture and in rural societies, where they are used for numerous purposes.

Straws, stovers and chaff have many uses within the farm economy, and these must be taken into account when assessing availability and profitability in livestock feeding systems. Non-agricultural uses include fuel and biofuel, construction (thatching, clay or concrete binder, plastering, insulation), crafts (basketry, mattresses, furniture), clothing (shoes, hats), paper (rice straw), etc. In agriculture, straws used to be an integral part of large-scale farming as feed and litter for the production of manure, which was essential to soil fertility until the advent of inorganic fertilizers and mechanization. With the mechanization of agriculture in industrial countries, straws were for some time thought to be of so little value that they were often burnt in the field, a practice that ceased with the passing of environmental legislation and the development of treatments that improve straw digestibility. At the small-scale farming and subsistence levels, the importance of straws never stopped and even grew due to decreasing access to free grazing. In any case, straws are still a major agricultural product and provide biomass (when ploughed into the soil), livestock fodder and livestock bedding, which in turn goes back to the soil as fertilizer. Straws are usually harvested, but they can be grazed by livestock (Suttie, 2000).

Many crop residues are called straw:

- Straw (or white straw) *stricto sensu* is the **dry stems (culms) and leaves of small cereals** such as wheat, barley, oat, triticale, rye and rice (click on the links to see the datasheets for each forage). In documents from temperate countries, the term *straw* without a species qualifier refers to a small cereal straw, and particularly to wheat straw. In tropical countries,

straw may refer to rice straw.
- Straw is sometimes used as a synonym for **stover, which is the stalks and leaves of larger cereal plants** such as maize (maize stover), sorghum (sorghum stover) and pearl millet. Sunflower stalks are also called straw or stover. Unlike small cereal straws, stover may be relatively fresh. Maize, sorghum and millet stovers are major forages in developing countries. Maize stover is also widely used in commercial agriculture.
- Straw is often a synonym for the **haulms and vines of legume crops** (pea, common bean, lentil, cowpea...), oil crops (rape, groundnut, soybean...), root crops (potatoes) or textile crops (flax). Legume straws are much more difficult to recover: in humid climates the leaves tend to discolour or drop at, or before, harvest, and in dry conditions they shatter. Where the final drying of the crop takes place at the homestead, it is easier to recover the leaves and stems.

It should be noted that the term straw used for other crops than small cereals can be a source of confusion. Essentially, straw, *stricto sensu*, is dry and does not usually include residual grains and chaff (very small pieces of straws mixed with grain husks and weed seeds). However, straws from legumes and other plants may be significantly moist and include other plant residues.

In livestock feeding, straws of all types are coarse, high-fibre, low-protein and low-digestibility roughages. They play an important role as fillers and they have some value as an energy source for feeding ruminants and pigs provided that they are adequately supplemented. In dry climates, well-harvested, stored and processed straws may have a nutritive value similar and in some cases better than dried, mature tropical grasses. In temperate areas, straws can be emergency feeds in periods of drought (Suttie, 2000).

While straws are typically of low nutritive value, their quality is variable and depends on species and variety. Legume straws generally have a higher nutritive value than cereal straw due to their higher protein content (Suttie, 2000). Soil fertility, rainfall, time of sowing, time of harvest and storage conditions also influence straw quality (Aitchison, 2005). Oat straw is considered to be more palatable than the straws of other cereals due to the absence of awns (Kruse, 2003; Warren, 2004).

This datasheet is mostly concerned with straws of small cereals from temperate countries (wheat, barley, oat, rye and triticale), since these straws are largely comparable from a nutritional point of view. However, processes that increase the nutritional value of straws tend to be common to most high-fibre roughages. Straws from tropical and subtropical cereals, stovers, legume straws and other crop residues are described in the datasheets of the corresponding plant forages, but comparisons between small cereal straws and other straws are discussed below.

Distribution

Straws are available wherever cereal or legume grain production occurs. Assuming that cereal straw production is slightly higher than the corresponding grain production, it can be estimated that 2 to 3 billion tons of straw were produced in the world in 2007 (FAO, 2011).

Processes

Straws are low quality roughages and there have been many attempts to improve their nutritive value through physical or chemical treatments.

Physical processes

Straws can be treated by grinding, soaking, boiling and fermenting. Grinding (also called chaffing or chopping) is the preferred method as other methods generally give poor results. In India, chopping straws and stovers reduced fodder wastage by 30% as animals could not select between leafy parts and dry stems (Chander, 2010a).

Chemical processes

Treating straw with chemicals can give a product of higher nutritive value, particularly when the untreated product is of very low nutritive value. The nutritional improvement depends on the plant family, species and variety: notably, legumes straws are less responsive to chemical treatments than cereal straws (Chenost et al., 1997). Chemical treatments are primarily designed to facilitate the attack of lignified cell walls by rumen micro-organisms: alkali treatments break lignin-carbohydrate linkages, resulting in the solubilization of lignin associated with polysaccharides and in the breaking of cellulose into smaller units. The treated straw is thus looser and easier to digest (Ramalho-Ribeiro, 1994). Most chemical treatments are alkali treatments: sodium hydroxide (NaOH), ammonia (NH_3) and urea. These methods tend to require large amounts of water and are therefore impracticable in areas where water supply is limited (Suttie, 2000; Chenost et al., 1997). Treatment with HCl has also been successfully tested on straw to be fed to sows (Gärsch et al., 1989).

Sodium hydroxide (NaOH) treatment

Wet treatment

The process consists in soaking the straw in 10 times its weight of a 1.3% NaOH solution at ambient temperature for about 24 hours. The liquid is drained off to be used for another batch of straw. An average of 7-8 kg of NaOH is required for 100 kg of straw. The straw is washed after treatment until it is free of alkali. Attempts have been made to reduce the amount of water required for the process, for example mixing 100 kg of straw with only 300 L of water and 6 kg of NaOH. After treatment, straw is washed according to the principle of chromatography (countercurrent), whereby the stream of water meets the flow of straw: this treatment has a tremendous effect on crude fibre digestibility.

If higher costs for chemicals are acceptable, the alkali can be neutralized with acetic acid rather than washed out. However, the high level of sodium in such materials may cause problems if fed in large amounts. Neutralization through ensiling also seems promising (Suttie, 2000).

Dry treatment

Another approach is to spray low concentrations of alkali on the feed (4 kg of NaOH per 160 kg of chopped straw) and to allow it to slake before feeding. The sprayed straw is pelleted so that the alkali comes in close contact with the fibre. The pellets are not neutralized before feeding. Another method consists in treating the straw for fifteen minutes in a hot (80-90°C) NaOH solution. The liquid is then pressed out of the treated straw before it is dried in a grass drier. The acid hot gases (carbon dioxide and sulphur dioxide) in the dryer neutralize the straw (Suttie, 2000).

Though NaOH treatment increases cell wall digestibility, it may be dangerous for the operators and it has no effect on nitrogen content (Ramalho-Ribeiro, 1994).

Ammonia (NH_3) and urea treatment

Ammonia treatment increases the digestibility of straw with the additional benefit of enriching it with nitrogen. Ammonia also acts as a fungicide as the process creates anaerobic conditions. Anhydrous ammonia or a 35% aqueous solution can be used when water is available. Gaseous ammonia is best suited to large operations but can only be used where the distribution system for ammonia (tankers, cylinders) is available (Suttie, 2000).

In a simple farm-scale application, the straw is baled loosely and placed on a plastic sheet, after which the straw is tightly and hermetically covered with plastic, and gaseous ammonia (3-4% of the weight of the straw) is let in through a hose. The straw can be used after 3 to 8 weeks, depending on temperature conditions (the lower the temperature, the longer the process), when the plastic is removed and the ammonia aired off. Ammonia treatment requires good moisture conditions (the straw moisture must range between 15 and 40%) which are not always easy to fulfil in drier areas. The ammonia treatment requires that providers of gaseous or anhydrous ammonia are available, which is not always the case (Chenost et al., 1997).

While developed countries use the direct ammoniation process for treating straw, treatment with urea has been proposed since the 1980s as a cheaper and safer alternative to NH_3 and NaOH treatment in tropical countries (Walli, 2010; Chenost et al., 1997). Urea mixed with moist straw releases ammonia throughout the following reaction:

$$CO(NH_2)_2 + H_2O \rightarrow 2\,NH_3 + CO_2$$

Facilitated by bacterial action, the process is rapid at high temperatures and is thus more suited to subtropical and tropical conditions than to temperate climates or subtropical winters. Because it releases ammonia, urea treatment has a similar effect on straw as anhydrous ammonia (Suttie, 2000). Depending on environmental conditions and especially temperature, urea-treated straws can be used between 2 weeks after treatment in dry tropical regions or on humid plains, and 3-5 weeks at higher altitudes in tropical areas where night temperatures can drop considerably (Ramalho-Ribeiro, 1994). Urea treatment should be timed to fit in with crop-harvesting operations and wherever possible done before the straw or stover has already been stored or stacked, to avoid double handling and extra labour. This will also help ensuring that the straw is in good condition; dirty, mouldy or rotten straw must never be treated as the end-product would be a poor and potentially dangerous feed (Suttie, 2000).

However, though urea treatment was "hugely extolled" as the most promising treatment for small-scale farms in tropical areas (Chander, 2010b), a 2010 report by the FAO showed that this technology could be considered a failure due to its poor adoption by farmers, except in China. Many reasons have been suggested among which the cost of urea, the time (and subsequent labour costs) needed and the insufficient water supply were the most important. Reducing labour requirements through the mechanical spraying of straw during harvest, or through the establishment of straw treatment cooperatives, might improve its adoption by a wider range of small farmers. The use of urine as cheap urea source was also proposed as a possible incentive factor for farmers (Owen et al., 2010).

Other chemical treatments

Sulphur dioxide, ozone and alkaline hydrogen peroxide are other possible chemical treatments. Sulphur dioxide and ozone treatments had a positive effect on rape straw degradability (Alexander et al., 1987).

Biological treatments

Many experiments have been done in order to increase the degradability of ligno-cellulosic material by the way of ligninolytic fungi or enzyme treatments. In wheat and rice straws, fungi such as *Aspergillus niger*, *Aspergillus awamori*, *Trichoderma reesei*, *Trichoderma viride* and *Phanerochaete chrysosporium* have yielded higher levels of reducing sugars than chemical treatments (Patel et al., 2009). Such methods could be a practical, environmental-friendly and cost-effective future approach for enhancing the nutritive value of straws (Sarnklong et al., 2010).

drilling management

Harvesting

It is generally preferable to store straw as much as necessary to cover the roughage needs of livestock through the lean season. Straw yield, recovery and quality can be improved without changing cultivars by attention to agronomic details at the time of harvest and immediately afterwards. Where the whole crop is cut at harvest, the straw should be dried as quickly and thoroughly as possible, and stored with care. Where heads or cobs are hand-gathered, the cutting and drying of the stover or straw should be done immediately after grain harvest is completed, with the fields protected from grazing livestock in the period between grain harvest and straw collection. Stooking of maize and sorghum allows final ripening of the grain after the plant is cut. This provides stover of better feeding value than if the crop is allowed to mature standing (Suttie, 2000).

Traditional harvesting method

In developing countries, straw is hand-cut a few days before full maturity to prevent shattering. It is then bound into sheaves that are let to ripen and dry in the field. The sheaves are threshened and yield grain and straw. The form of straw depends on the threshing method. Threshing by flails or by mechanical threshers produces long straw. Treading by animals (horses or draught oxen) or with a ridged roller breaks straw into 5-10 cm long pieces. Straws can be chaffed during threshing, resulting in short straw pieces. After threshing, straw often remains unbaled. It can be stored in the field on the ground where it can be covered with mud or plastic sheeting to protect it from rain and livestock, or stored in trees or on roof tops so that livestock cannot reach it. Mud covering can be used to seal stacks for urea treatment (Suttie, 2000).

In small-scale farm systems, maize, sorghum and millet stover is usually handled and dried in the long, unchopped state, often by stooking (sheaf bundling) in, or on the boundary of the field prior to storage. Where dried roughage is highly valued and there is a dry season after harvest, stovers are usually dried in sheaves. In dry areas they are often stored by stacking the sheaves together with the stems more or less vertical. In large-scale systems stover may be baled, but it can also be collected by forage-harvester and ensiled with or without urea treatment (Suttie, 2000).

Mechanized harvesting method

In industrialized countries, fully mature cereals are harvested with combine-harvesters. Straws are thus of lower value as the leaves are drier and the nutritive value drops with maturity. Moreover, herbicides suppress weeds which can increase the nutritive value of the straw (Suttie, 2000). Straws are generally baled in square or round bales of variable size and weight. The chaff is removed from the straw and used as bedding material or as feed. Removing chaff from the field and feeding it to livestock is a conservation method as it allows no-till methods by removing weed seeds (Carton, 2009).

Stubble and stover grazing

Some harvesting methods leave the plants (or parts of the plant) standing after the heads or cobs have been removed. This is common in small-scale farm systems for rice, maize, pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*) and sorghum. Where feed is plentiful or where labour is scarce, this stubble may be grazed directly by livestock, which is advantageous since stubble may have a higher nutritional value due to the presence of unharvested grains and weeds. Animals graze it selectively and may find a maintenance diet from what might be a sub-maintenance feed if taken as a whole. However, this technique causes a lot of wastage through trampling and is not advisable where there is an overall shortage of roughage for the dry season or winter (Suttie, 2000).

Stovers are still grazed in some countries, especially in parts of Africa. This is wasteful but does save a lot on labour and returns some organic matter to the fields (Suttie, 2000).

Environmental impact

Environmental services

The use of straw for numerous agricultural and non-agricultural activities of straw makes it one of the foremost and most ancient multi-purposes agricultural by-product. Vast quantities of biomass and energy are recycled through the use of straw for feed, fuel and fertilizer.

Environmental and health issues with straw treatments

Health hazards

Chemical treatments of straws may have deleterious impacts on health and the environment. Alkali treatments may be potentially dangerous for operators as they may cause eye and skin burns when not properly used (Ramalho-Ribeiro, 1994).

Water contamination

When straws are treated with urea, the necessary high moisture content of the final product (more than 30%) requires the addition of large amounts of water at the beginning of the process. Because NH_3 is hygroscopic and remains in water, and because straw does not retain high levels of water, urea treatment can result in NH_3 leaching from the bottom of the silo (Ramalho-Ribeiro, 1994).

datasheet citation

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English corrected by Tim Smith (Animal Science consultant) and Hélène Thiollet (AFZ)

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Straws

Nutritional attributes

Straws are rich in fibre and poor in nutrients including protein, sugars, minerals and vitamins. Straws from cereals and grasses (Poaceae) are generally of lower nutritional value than straws from other plant families. The leaf:stem ratio as affected by harvesting conditions may determine to a great extent the nutritive value of straw, especially for legume species, and leaf loss should be prevented if the straw is going to be used as an animal feed (Lopez et al., 2005). The following table shows the average (and range) protein and fibre content of straws from cereals and legumes (Feedipedia, 2013):

Type of straws	Cereals and grasses	Vegetables
Crude protein % DM	4.1 ± 1.4 (0.6-11.4)	10.5 ± 2.9 (3.4-18.2)
Crude fibre % DM	39.9 ± 4.4 (20.1-54.6)	34.8 ± 8.3 (13-55.3)
NDF% DM	73.7 ± 7.9 (38.4-89.4)	54.2 ± 10.9 (21.2-86.4)
ADF % DM	45.6 ± 5.8 (28.3-59.3)	43.9 ± 8.8 (15-71.5)
Lignin % DM	6.5 ± 2 (0.9-13.2)	10 ± 2.7 (3.5-18.4)
Number of observations	1146	390

The composition of straws depends on the species and, like other crop residues, on the proportions of stems, leaves and other material such as soil. Cereal and grass straw contains about 4% DM protein *vs.* about 10% for legume straws. The crude fibre and ADF levels are roughly similar (35-40% DM) but cereal straws tend do be much richer in NDF (about 74% DM) than legume straws (about 54% DM). The latter, however, are more lignified (10% lignin *vs.* 6.5% DM for cereal straw). Straws are poor in sugars and starch (less than 2% for wheat straw). Temperate cereal straws (wheat, barley, oats) tend to have relatively low levels of mineral matter (5-7% DM) but other cereal species, like rice, are rich in minerals (18% DM).

Oat and barley straw are generally considered to be more nutritious and palatable than wheat straw. In western Europe, untreated wheat straw is considered to be very poor, and not fed except in an emergency. In the UK, oat and barley straw were the only ones recommended as feed until modern straw-treatment techniques were introduced. In the traditional wheat-growing countries of Asia and North Africa, however, wheat straw is highly prized and great care is taken in collecting and storing it. The straw of foxtail millet (*Setaria italica*), which is an important crop in north-western China, is well accepted by livestock. In India and Nepal, finger millet straw (*Eleusine coracana*) is considered a good feed. The straw of common millet (*Panicum miliaceum*) is hairy and its palatability is mediocre (Suttie, 2000).

Potential constraints

Toxicity of urea and ammonia-treated straws

Treating straw with urea or ammonia can cause toxicity in ruminants. Large amounts of urea entering the rumen may result in the production of excess NH_3 by the rumen bacteria. Part of this ammonia cannot be fully detoxified by the liver and passes into the blood stream, causing ataxia (at 29 mg/L blood in cattle) or death (at 42 mg/L in cattle and 32 mg/L in sheep) (Rogers, 1999). It is thus important that livestock is progressively introduced to treated straws so that rumen bacteria can adapt to the increased levels of urea, thus preventing the sudden release of NH_3 in the rumen (Suttie, 2000; Rogers, 1999).

Other concerns

Concerns about straws tend to be specific. For instance, some straws (wheat, barley) contain awns that may lower their palatability. Some legumes, like faba bean (*Vicia faba*) have coarse, woody stems (Suttie, 2000). The high fibre content of oat straw is known to cause digestive and bowel occlusions (phytobezoars) in horses (Kohnke et al., 1999). The straw of chickpea (*Cicer arietinum*) has a very high oxalic acid content, is unpalatable, and reputed to be toxic (Suttie, 2000).

ruminants

Straws are generally bulky and the feeding value of untreated straws for ruminants is rather low: the OM digestibility of straws is in the 42-54% range. Their ingestibility is low: it is higher for sorghum, faba bean, pea and grasses than for rice, wheat, barley and oat (INRA, 2007). The nutritive values of legume straws are intermediate between those of medium-quality hays and those of cereal straws (Lopez et al., 2005).

Large differences in degradation can be observed within the same species, as reported for barley straw (Capper et al., 1992) and rice straw (Vadiveloo, 1992; Abou-El-Enin et al., 1999; Agbagla-Dohnani et al., 2001). In ruminants, oat straw is more palatable than barley straw, while barley straw is more palatable than wheat straw (Hamilton, 2010). However, despite their poor feeding value, straws can be useful during dry periods when high quality forages are lacking. Straws must be harvested well dried, and stored in a dry place.

Straw digestibility is limited both by its lignification and by its low nitrogen content. The digestibility and the rate of rumen passage can be increased by supplementing the straw with protein concentrate or urea plus minerals. It may also be economical to increase the nutritive value of straws by physical or chemical treatments (Göhl, 1982).

Effect of treatments on intake and digestibility

The feeding value of straw can be improved by grinding or by treatment with alkalis such as NaOH and ammonia.

Physical treatment

Grinding improves the ingestibility of straws, but not its energy or nitrogen value. Grinding also deprives the animal of the opportunity to reject the fibrous parts, thus reducing the digestibility of the feed, although this disadvantage is usually counterbalanced by the higher voluntary feed intake. For example, grinding wheat straw, even rather coarsely, can result in a 20-30% increase in intake because of the faster rate of passage through the rumen (Göhl, 1982). The following table shows the effect of combining grinding and NaOH treatment on barley straw fed to sheep (Fernandez-Carmona et al., 1972):

Chopped straw	Untreated	16% NaOH
OM digestibility (%)	45	61
DM intake (g/kg $W^{0.75}$)	27	48
Digestible energy intake (MJ/kg $W^{0.75}$)	0.19	0.48
Ground straw	**Untreated**	**16% NaOH**
OM digestibility (%)	45	64
DM intake (g/kg $W^{0.75}$)	36	54
Digestible energy intake (MJ/kg $W^{0.75}$)	0.25	0.55

Such increases in digestible energy intake can result in much greater performance. For instance, there have been reports of a 50% increase in the daily gains of beef cattle fed on all-roughage diets. It should be noted that the increased intake of digestible energy raises the protein requirement as well. When ground forage is mixed with concentrates, grinding tends to eliminate the difference in forage quality (Göhl, 1982).

NaOH treatment

NaOH treatment can increase the organic matter digestibility of wheat straw from 46% to more than 70%. Chromatographically treated wheat straw has a crude fibre digestibility of about 90%. An additional benefit is that straw treated with NaOH becomes softer, so less energy is lost in chewing and digestion. NaOH-treated straw is palatable and can be consumed in large quantities by livestock. Beef cattle can be fed up to 20 kg of treated straw per day, dairy cows up to 15 kg, young heifers up to 10 kg and sheep up to 3 kg. However, as noted previously, NaOH treatment is expensive and dangerous and does not improve the nitrogen value of the straw (Göhl, 1982).

Ammonia or urea treatment

Ammonia treatment (by the addition of anhydrous NH_3 or urea) is easier to do in practice than NaOH treatment, and more valuable since it improves ingestibility, digestibility and nitrogen content (Baumont, 2011).

In sheep, the increase in voluntary intake induced by NH_3-treatment is on average + 5 g/kg BW in sheep. In cattle, data are scarce but are of the same order of magnitude (+ 1.8 kg/d for steers and heifers; Baumont, 2011). This is far from being negligible given the low ingestibility of untreated straws (*e.g.* 11-12 g/kg BW in sheep and heifers for a barley straw; Dulphy et al., 1994). The increase in OM digestibility is on average 10-12 percentage points for wheat, barley, sorghum and maize, but is lower for rice (on average 4 points), which is initially more digestible. The increase in digestibility of crude protein is on average 6.2-6.5%, and an extra 14-20 g/kg DM of PDIN (true protein absorbable in the small intestine when N is limiting in the rumen) for wheat, barley and rice straws. For sorghum, crude protein digestibility is increased by 9.6%, with an extra 38 g/kg DM of PDIE (true protein absorbable in the small intestine when energy is limiting in the rumen). Ammonia-treated straws have an energy value and ingestibility comparable to that of late cut grass hays, but their nitrogen value remains lower (INRA, 2007; Baumont, 2011).

Supplementation

Straw is generally combined with other forages such as hay or silage, but it can be used as sole forage with supplementation where more nutritive forages are scarce. The first objective of supplementation is to meet the requirements of the rumen microbes in order to improve straw digestibility. Soluble nitrogen and fermentable carbohydrates can be provided by liquid feeds (such as a molasses-urea mixture included at 5-10% by weight of straw), protein concentrate (100 g of soybean meal or 150 g rapeseed meal per kg straw), by-products (corn gluten feed, DDGS and other maize processing by-products, rice bran), or legume forages such as leucaena leaves (*Leucaena leucocephala*). Minerals, trace elements and vitamins must also be provided. The second objective is to meet the energy and nitrogen requirements of the animal without affecting the cellulolytic activity of rumen microbes. Cracking or coarsely grinding cereal grains must be preferred to fine grinding in order to avoid an excess of rapidly fermentable carbohydrates. When a high level of concentrates is required, fibrous concentrates such as beet pulp, bran or corn gluten feed can be used (Devun et al., 2011).

Straw can be the main forage for heifers older than 15 months, and for suckling cows before the 8^{th} month of pregnancy, provided that their body condition score is sufficient. For younger heifers and for early calving suckling cows or animals with a low body condition score, other forages must be offered with the straw. For dairy cows and fattening steers, straw is mainly used to meet appetite and to ensure adequate rumen function as well as a fractioned distribution of concentrate among the day. Straw must be offered as long particles, *ad libitum* and several times per day (Devun et al., 2011). Urea-treated rice straw is sometimes used as roughage for milking cows in dairy farms (*e.g.* in Northern Thailand) but requires a true protein supplement (Sruamsiri, 2007).

In fattening lambs, straws can result in a performance similar to that obtained with hay. Ewes have a limited intake capacity and at least 500 g/d of good quality hay must be given with the straw (1-1.5 kg/d) from late pregnancy to early lactation (Devun et al., 2011).

Specific information on straws

For detailed information on the use of specific straws in ruminants, see the datasheets for those species in **Related feeds** on the "Description" tab.

Pigs

Straws are a highly fibrous and nutrient-poor material and thus only have a limited use in pig nutrition. However, they are used in pig farming both as a foraging substrate for behavioural purposes and/or as a feed for diluting dietary energy.

Sows

Supplying pregnant sows with straw was found to be effective in preventing bar and chain manipulations and in reducing stereotypic behaviour (Stewart et al., 2011; Veum et al., 2009; Whittaker et al., 1998; Spoolder et al., 1995).

In lactating sows, untreated ground straw had a reducing effect on milk production as excessive straw consumption reduced energy intake (Kempen et al., 1977). This dilution of dietary energy was found to be useful in pregnant sows, as it prevents them being overweight at farrowing, which can be deleterious to piglet survival (Dourmad et al., 1994). Including straw in the diet resulted in higher or unchanged sow performance, litter size and litter weight at birth and weaning (Veum et al., 2009; Guillemet et al., 2007; Gärsch et al., 1989). The effects of a high fibre diet on duration of parturition are debated. This duration was reduced in sows fed a 7% straw diet (Morgenthum et al., 1988).

In sows kept at low temperatures, wheat straw included at 22% together with wheat grain or dehydrated alfalfa meal reduced methane emissions and resulted in increased extra heat production (Noblet et al., 1988).

Growing and fattening pigs

Straw has a negative effect on digestibility and energy availability in growing pigs. For instance, in animals fed up to 30% barley straw in the diet, an increase in crude fibre from barley straw by 1% depressed the digestibility of gross energy by 2.9% (2.1 percentage points) and depressed the efficiency of utilization of metabolizable energy by 1.0% (0.7 percentage points) (Just, 1982). In fattening pigs, dilution of dietary energy can be used to limit fatness during the second stage of fattening when *ad libitum* feeding may result in the pigs being overweight. The inclusion of 10-15% wheat straw for fattening pigs was found to decrease the digestibility of protein, NDF, hemicellulose and gross energy (Falkowska et al., 2006), and to negatively affect daily gain and feed conversion ratio (Kozera et al., 2006). These results are partly consistent with former results that indicated that straw inclusion (8 or 16%) decreased intake of metabolizable energy and fat retention but that animal performance depended on the sex of animals (unchanged performance and lean tissue growth rate in castrated male pigs but slightly decreased performance in females) (Hakansson et al., 2000).

Poultry

In regions where straw is available at low cost, it is often used as a bedding material in poultry sheds. Straws have no value for poultry feeding: due to their high fibre content, they provide no energy or usable nutrients. In some conditions, straw can help to increase the proportion of fibre in diets of layers or male breeders (Hetland et al., 2004; de Jong et al., 2005). It can be practical to use finely ground straw as a filler for low energy diets, although the same effect could be obtained by selecting a higher proportion of fibre-rich ingredients through feed formulation.

Horses and donkeys

Straw from cereal grains can be fed to horses almost exclusively as a fibre source and can be used to replace all of the hay if the diet is properly supplemented with protein and minerals: for example, free-choice straw supplemented 2.2 to 3.2 kg of a 16% protein grain mix or 2.2 to 3.2 kg of alfalfa (Warren, 2004). However, straw is best used to replace only a portion of the hay and is a way to bypass buying additional hay when feeding a horse with high energy needs (Warren, 2004; Kruse, 2003). When feeding straw, water should be made available to reduce the risk of impaction colic. Straw should be gradually introduced in the diet over two weeks to give the horse's digestive system time to adjust to the fibre. It should not be fed to weanlings or yearlings because they do not have the digestive capacity or ability to utilize straw as efficiently as mature, adult horses (Warren, 2004). Straws contain about half of the phosphorus needed for a mature horse (Kruse, 2003).

datasheet citation

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Straws

Description | Nutritional aspects | Nutritional tables | References

Tables of chemical composition and nutritional value

- Wheat straw
- Barley straw
- Oat straw
- Triticale straw
- Rye straw
- Tef (Eragrostif tef), aerial part, straw

Avg: average or predicted value; SD: standard deviation; Min: minimum value; Max: maximum value; Nb: number of values (samples) used

Wheat straw

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	91.0	1.3	87.3	93.8	438
Crude protein	% DM	4.2	0.7	2.6	6.0	428
Crude fibre	% DM	41.5	2.1	36.6	46.2	438
NDF	% DM	77.5	4.2	65.4	86.0	85 *
ADF	% DM	50.0	3.5	43.3	57.0	80 *
Lignin	% DM	7.2	1.0	5.3	9.7	203
Ether extract	% DM	1.4	0.5	0.7	2.8	53
Ash	% DM	6.7	1.2	4.4	10.0	433
Starch (polarimetry)	% DM	1.0	0.6	0.1	2.6	114
Total sugars	% DM	1.2	0.9	0.3	5.7	138
Gross energy	MJ/kg DM	18.5	0.6	16.0	18.5	18 *

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	4.8	1.1	2.8	7.9	226
Phosphorus	g/kg DM	0.7	0.2	0.3	1.2	226
Potassium	g/kg DM	11.2	4.6	5.4	21.2	40
Sodium	g/kg DM	0.1	0.1	0.0	0.4	143
Magnesium	g/kg DM	1.2	1.2	0.4	5.4	18
Manganese	mg/kg DM	32	19	12	60	5
Zinc	mg/kg DM	17	7	8	28	10
Copper	mg/kg DM	4	2	2	9	10
Iron	mg/kg DM	184	201	52	643	8

Secondary metabolites	Unit	Avg	SD	me	Max	Nb
Tannins (eq. tannic acid)	g/kg DM	2.5				1
Tannins, condensed (eq. catechin)	g/kg DM	0.2				1

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, ruminants	%	48.4	4.8	38.7	55.2	27 *
Energy digestibility, ruminants	%	45.2		37.4	46.7	2 *
OF ruminants	MJ/kg DM	8.3				*
ME ruminants	MJ/kg DM	6.8		5.4	6.8	2 *
ME ruminants (gas production)	MJ/kg DM	5.0	0.9	4.1	5.8	3
Nitrogen digestibility, ruminants	%	3.5	49.5	-69.3	85.0	15 *
a (N)	%	38.4				1
b (N)	%	25.5				1
c (N)	h-1	0056				1
Nitrogen degradability (effective, k=4%)	%	53				*
Nitrogen degradability (effective, k=6%)	%	51				*

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	12.3				*

DE growing pig	MJ/kg DM	2.3				*
MEn growing pig	MJ/kg DM	2.0				*
DO growing pig	MJ/kg DM	1.1				*

Rabbit nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, rabbit	%	18.8				*
OF rabbit	MJ/kg DM	3.5	2.7	1.2	6.4	3
MEn rabbit	MJ/kg DM	3.3				*
Nitrogen digestibility, rabbit	%	60.0	33.9	35.1	98.7	3

The asterisk * indicates that the average value was obtained by an equation.

References

AFZ, 2011 ; Ait Amar, 2005 ; Alawa et al., 1984 ; Alibes et al., 1990 ; Al-Masry, 2003 ; Arieli et al., 1989 ; Aufrère et al., 1988 ; Belibasakis 1984 ; Belibasakis 1984 ; Carvalho et al., 2006 ; Chandra et al., 1971 ; Chermiti 1997 ; CIRAD 1991 ; Das et al., 1999 ; Blas et al., 1989 ; De Boever et al., 1994 ; Demarquilly 1987 ; Denek et al., 2004 ; Doyle et al., 1990 ; Dutta et al., 2004 ; Egan et al., 1975 ; Egan, 1974 ; Fernandez Carmona et al., 1996 ; Friesecke 1970 ; Gippert et al., 1988 ; Gowda et al., 2004 ; Grimit 1984 ; Habib et al., 1995 ; Haddad et al., 2001 ; Horton 1979 ; IAV 2009 ; Ibrahim et al., 1990 ; Jain et al., 1980 ; Kamra et al., 1989 ; Khanum et al., 2007 ; Kromann et al., 1977 ; Lindberg et al., 1982 ; Lindberg, 1981 ; Lopez et al., 2005 ; Maan et al., 2003 ; Maertens et al., 1981 ; Mann et al., 1988 ; Mason et al., 1988 ; McCann 1985 ; McCartney et al., 2006 ; Miraglia et al., 1985 ; Molénat 1995 ; Morgan et al., 1984 ; Mosi et al., 1985 ; Nandra et al., 1993 ; Noblet et al., 1989 ; Nsahlai et al., 1996 ; Parthasathy et al., 1982 ; Peteva-Vantcheva et al., 1976 ; Pozy et al., 1996 ; Rasool et al., 1998 ; Sehu et al., 1998 ; Shand et al., 1983 ; Sharma et al., 2008 ; Shi et al., 1993 ; Singh et al., 2005 ; Singh et al., 2011 ; Sudana et al., 1986 ; Weaver et al., 1989 ; Turgut et al., 2004 ; Wainman et al., 1984 ; Weston et al., 1988 ; Weston et al., 1989 ; Weston 1989 ; Wolter et al., 1979 ; Wolter et al., 1982

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Barley straw

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	90.9	2.5	85.4	95.0	32
Crude protein	% DM	3.8	1.0	1.9	6.0	52
Crude fibre	% DM	40.5	4.1	32.9	46.7	27
NDF	% DM	80.5	4.8	69.7	89.1	36
ADF	% DM	48.3	4.9	38.7	57.9	35
Lignin	% DM	6.5	1.5	4.1	9.0	25
Ether extract	% DM	1.4	0.7	0.6	3.8	16
Ash	% DM	7.5	2.9	3.5	17.6	52
Gross energy	MJ/kg DM	18.2	0.6	17.5	18.6	3 *

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	4.6	1.5	3.0	8.2	10
Phosphorus	g/kg DM	1.0	0.7	0.2	2.3	10
Potassium	g/kg DM	14.4	5.1	8.2	20.6	4
Sodium	g/kg DM	0.9	0.4	0.5	1.6	6
Magnesium	g/kg DM	1.2	0.3	0.7	1.4	5
Manganese	mg/kg DM	28	10	17	37	3
Zinc	mg/kg DM	15	5	11	21	4
Copper	mg/kg DM	10	13	3	thirty	4
Iron	mg/kg DM	177	55	124	250	4

Secondary metabolites	Unit	Avg	SD	me	Max	Nb
Tannins (eq. tannic acid)	g/kg DM	3.6				1
Tannins, condensed (eq. catechin)	g/kg DM	0.2				1

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, ruminants	%	47.5	2.0	43.0	50.2	19 *
Energy digestibility, ruminants	%	44.1				*
OF ruminants	MJ/kg DM	8.0				*
ME ruminants	MJ/kg DM	6.5				*
ME ruminants (gas production)	MJ/kg DM	6.0				1
Nitrogen digestibility, ruminants	%	22.8	22.3	0.0	63.1	8
a (N)	%	30.3				1
b (N)	%	26.5				1
c (N)	h-1	0084				1
Nitrogen degradability (effective, k=4%)	%	48				*
Nitrogen degradability (effective, k=6%)	%	46				*

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	13.9				*
DE growing pig	MJ/kg DM	2.5				*
MEn growing pig	MJ/kg DM	2.2				*
DO growing pig	MJ/kg DM	1.2				*

The asterisk * indicates that the average value was obtained by an equation.

References

Abate et al., 2009 ; Abbeddou and al., 2011 ; Abidin et al., 1981 ; AFZ, 2011 ; Agbagla et al., 1993 ; Jongho Ahn et al., 1997 ; Alawa et al., 1986 ; Alawa et al., 1988 ; Alibes et al., 1990 ; Blümmel et al., 1993 ; Bochi-Brum et al., 1999 ; Capper et al., 1989 ; Chehma et al., 2001 ; Chermiti 1997 ; CIRAD 1991 ; Djouvinov et al., 1998 ; Dryden et al., 1983 ; Economides, 1998 ; Friesecke 1970 ; Grimit 1984 ; Guedas et al., 1973 ; Haddad, 2000 ; Hadjigeorgiou et al., 2001 ; Hadjipanayiotou 1984 ; IAV 2009 ; Israelsen et al., 1978 ; Kerckhove and al., 2011 ; Lopez et al., 2005 ; Madrid et al., 1997 ; Martin-Orue et al., 2000 ; McCann 1985 ; McCartney et al., 2006 ; Miraglia et al., 1985 ; Nsahlai et al., 1996 ; O'Shea et al., 1986 ; Paduano et al., 1995 ; Rogerson, 1956 ; Sehu et al., 1998 ; Singh et al., 2011 ; Weaver et al., 1989 ; Turgut et al., 2004 ; Wheeler et al., 1979 ; Wilkinson et al., 1978

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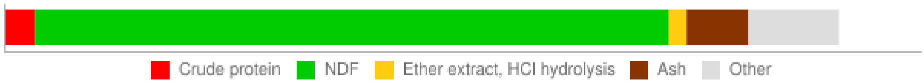
Oat straw



Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	89.6	5.1	78.6	93.9	7
Crude protein	% DM	3.6	0.9	2.2	6.0	45
Crude fibre	% DM	39.8	5.1	29.6	46.8	18
NDF	% DM	76.0	4.7	67.9	82.7	25
ADF	% DM	44.6	4.7	38.0	52.3	35
Lignin	% DM	6.6	0.5	5.8	7.6	17
Ether extract	% DM	1.5	0.6	0.7	2.3	9
Ether extract, HCl hydrolysis	% DM	2.1	0.9	1.4	3.1	3
Ash	% DM	7.4	1.7	4.8	10.0	34
Gross energy	MJ/kg DM	18.0	0.3	17.9	18.6	6 *

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	2.5	0.9	1.0	3.3	5
Phosphorus	g/kg DM	1.2	0.7	0.2	2.4	6
Potassium	g/kg DM	14.7	3.9	10.4	18.0	3
Sodium	g/kg DM	2.0	1.1	0.7	2.7	3
Magnesium	g/kg DM	1.1	0.4	0.7	1.5	3
Manganese	mg/kg DM	33	14	22	48	3
Zinc	mg/kg DM	20	6	15	27	3
Copper	mg/kg DM	5	2	3	7	3
Iron	mg/kg DM	99				1

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, ruminants	%	48.2	5.5	38.8	58.0	15 *
Energy digestibility, ruminants	%	44.7		43.1	44.7	2 *
OF ruminants	MJ/kg DM	8.1				*
ME ruminants	MJ/kg DM	6.6		6.3	6.6	2 *
ME ruminants (gas production)	MJ/kg DM	5.1				1
Nitrogen digestibility, ruminants	%	31.0	45.0	-49.7	85.0	9

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	15.0				*
DE growing pig	MJ/kg DM	2.7				*
MEn growing pig	MJ/kg DM	2.4				*
DO growing pig	MJ/kg DM	1.3				*

The asterisk * indicates that the average value was obtained by an equation.

References

AFZ, 2011 ; Alibes et al., 1990 ; Barua et al., 1951 ; Butterworth et al., 1986 ; Campling et al., 1966 ; Chermiti 1997 ; Egan, 1974 ; Freer et al., 1962 ; Grimit 1984 ; Guedas et al., 1973 ; Lopez et al., 2001 ; Lopez et al., 2005 ; Mason et al., 1988 ; McCartney et al., 2006 ; Mosi et al., 1985 ; Nandra et al., 1993 ; Nsahlai et al., 1996 ; Pozy et al., 1996 ; Rogerson, 1956 ; Sauvant et al., 1985 ; Sehu et al., 1998 ; Shand et al., 1983 ; Singh et al., 2011 ; Spragg et al., 1986 ; Weaver et al., 1989 ; Wainman et al. 1984

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Triticale straw

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	92.5	2.3	90.1	95.0	5
Crude protein	% DM	3.2	1.0	2.1	4.1	5
Crude fibre	% DM	39.2	3.2	35.4	42.9	5
NDF	% DM	75.1				*
ADF	% DM	47.5				*
Ether extract	% DM	2.2	0.1	2.1	2.4	4
Ash	% DM	5.4	1.4	4.1	7.7	5
Gross energy	MJ/kg DM	18.7				*

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	2.7	1.0	1.3	3.6	4
Phosphorus	g/kg DM	0.3	0.2	0.1	0.4	4
Potassium	g/kg DM	12.0	2.1	9.3	14.4	4
Sodium	g/kg DM	0.1		0.0	0.1	2
Magnesium	g/kg DM	0.7	0.4	0.4	1.2	4

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, Ruminant	%	49.9				*
Energy digestibility, ruminants	%	46.9				*
OF ruminants	MJ/kg DM	8.8				*
ME ruminants	MJ/kg DM	7.2				*

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	16.1				*
DE growing pig	MJ/kg DM	3.0				*
MEn growing pig	MJ/kg DM	2.7				*
DO growing pig	MJ/kg DM	1.4				*

The asterisk * indicates that the average value was obtained by an equation.

References

Alibes et al., 1990 ; CIRAD 1991 ; Pozy et al., 1996

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Rye straw

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	92.0		91.6	92.4	2
Crude protein	% DM	4.1	1.9	2.5	6.7	4
Crude fibre	% DM	41.9		39.3	44.4	2
NDF	% DM	77.9				*
ADF	% DM	50.3		42.4	54.4	2 *
Lignin	% DM	9.0		5.5	12.4	2
Ash	% DM	7.7	4.2	3.8	12.2	3
Gross energy	MJ/kg DM	18.3				*

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	4.1				1
Phosphorus	g/kg DM	1.3				1
Potassium	g/kg DM	12.2				1
Magnesium	g/kg DM	1.4				1
Manganese	mg/kg DM	18				1
Zinc	mg/kg DM	12				1
Copper	mg/kg DM	3				1
Iron	mg/kg DM	54				1

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb

OM digestibility, Ruminant	%	48.2				*
Energy digestibility, ruminants	%	44.8				*
OF ruminants	MJ/kg DM	8.2				*
ME ruminants	MJ/kg DM	6.6				*
ME ruminants (gas production)	MJ/kg DM	5.1				1
Nitrogen digestibility, ruminants	%	2.0				*

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	11.9				*
DE growing pig	MJ/kg DM	2.2				*
MEn growing pig	MJ/kg DM	1.9				*
DO growing pig	MJ/kg DM	1.0				*

The asterisk * indicates that the average value was obtained by an equation.

References

Alibes et al., 1990 ; Guedas et al., 1973 ; Lopez et al., 2005 ; McCartney et al., 2006

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Tef (Eragrostif tef), aerial part, straw

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	91.6	1.0	89.0	94.4	444
Crude protein	% DM	4.1	1.1	1.8	7.3	429
Crude fibre	% DM	35.8		33.2	38.4	2
NDF	% DM	70.9	3.3	68.4	83.8	418
ADF	% DM	41.7	3.2	37.9	52.2	111
Lignin	% DM	5.8	1.1	3.3	8.5	110 *
Ether extract	% DM	1.9				1
Ash	% DM	7.9	1.3	3.7	12.4	228
Gross energy	MJ/kg DM	18.1		17.1	18.1	2 *

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	3.0	1.1	1.4	6.2	50
Phosphorus	g/kg DM	1.4	0.6	0.2	2.7	76
Potassium	g/kg DM	12.0	2.1	6.5	18.4	46
Sodium	g/kg DM	0.1	0.1	0.0	0.2	41
Magnesium	g/kg DM	1.5	0.3	0.8	2.3	45
Manganese	mg/kg DM	134	127	22	371	43
Zinc	mg/kg DM	25	10	13	67	41
Copper	mg/kg DM	10	5	3	26	41
Iron	mg/kg DM	176	83	66	320	43

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, ruminants	%	57.0	4.6	45.4	57.0	3 *
Energy digestibility, ruminants	%	53.6				*
OF ruminants	MJ/kg DM	9.7				*
ME ruminants	MJ/kg DM	7.9				*
Nitrogen digestibility, ruminants	%	15.6	12.7	1.0	24.3	3
a (N)	%	16.9				1
b (N)	%	37.5				1
c (N)	h-1	0030				1
Nitrogen degradability (effective, k=4%)	%	33				*
Nitrogen degradability (effective, k=6%)	%	29				*

The asterisk * indicates that the average value was obtained by an equation.

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